

The Potential of LiDAR Application in Malaysia

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Abstract-Remote sensing technology has grown over time and will continue in the future. Malaysia is aware of the emerging of remote sensing technology including LiDAR system in the market. The technology can offers an advantages and benefits in managing natural resources. Dealing with advance sensing technologies and analytical tools to support site-specific economic, environmental, and sustainable decision making, the accurate, timely and detailed spatial information or features characterization are requires. Despite of the current use of high resolution satellite and airborne sensing, LiDAR is a promising alternative tool to be used in especially in forestry sector. This is possible by utilization of accurate measurement forestry data and information to improve operations and processes. As a newcomer in LiDAR technology this paper gives a synopsis of LiDAR sensing technology application and its potential to Malaysia.

Keywords-precision forestry; LiDAR technology; potential application

I. INTRODUCTION

The adoption of precision forestry concept is not new but in Malaysia is still at infancy stage. It deals with advanced sensing technologies and analytical tools to support site-specific economic, environmental, and sustainable decision making for forest management and development (Mohd Hasmadi *et al.*, 2007). Precision forest management is a business of geoinformatics technology. The use of geoinformatics for precision forest management has become popular in developing country but at different stages. Precision forestry leverages advanced technology and tools to support sustainable decision making, where it is highly reliant on accurate, timely, repeatable, detailed and spatially explicit forest inventory characterizations and structural information (Jason *et al.*, 2002). Forest applications that are based solely, mainly or partly on remote sensing technology are structured by data type. Beginning with basic to in-depth description of the user requirements lead to an increased demand for up to date, reliable and applicable on forest information for effective monitoring system. Forest measurement through traditional surveying has gained the development of new measurement tools. The rapid development of the image processing has made possible to combine digital data so that the aerial or even satellite imagery can be used to find the tops of the trees, estimate tree lengths, dbh sizes and thus volumes. The measurements of height and vertical structure of forest structure open a wide application in the forest ecosystem especially in combination with other optical data. In addition images does not necessarily be taken from the spaceborne or airborne. The different tree species , their location,

characteristic , etc can be identified and analysed by using radar scanning tecnology such as LiDAR.

LiDAR is an innovative technology that assists the assessment of forest conditions as well as establishing a viable approach to long-term monitoring to support the management of natural forests. The LiDAR ability is rapidly collect highly accurate three-dimensional information of the forest and it ecosystem and make a significant impact in overcoming the challenges faced by government agencies and non-governmental and organizations (NGOs) to solve new challenge in reducing emissions from deforestation and degradation initiatives. Meanwhile image processing software and techniques supports the advance data, providing greater analytical capabilities, thus improved knowledge, than was previously possible. LiDAR have been effectively demonstrated and reported in precision forestry applications, including forest height inventory assessment (Andersen *et al.*, 2006), multiple resource inventory (Reutebuch *et al.* 2005), ecosystem studies (Lefsky *et al.*, 2002) and stand value estimates (Murphy 2008). The ability of LiDAR is expanding for the assessment of ecosystem services (Richardson *et al.*, 2009) and biomass estimation (Popescue *et al.*, 2004). This paper gives a synopsis of LiDAR sensing technology application and its potential to Malaysian forestry. The current state of application and challenges toward possible direction of forest resources management also highlighted. This demonstrates the use and need of future precision forestry application of LiDAR technologies. Thus we believe that LiDAR technology integrated with geoinformatic procedures and efficient field sampling technique could provide a fundamental data for ecologically, socially and economically sustainable forest management in the future.

II. INFORMATION NEEDS IN PRECISION FORESTRY

Forest information requirements are increased over time and will continue in the future. Information is changing where the data in not just as before most of the focus is on the timber resources for commercial use. In modern forest management the society has move from an economic focus toward multi-purpose or multi-functional forestry. In order to support the spirit of multi-functional forest multi-resources, an inventory is essential. Precision data reflects more attention by the society and policy for understanding the forest as a complex ecosystem that supporting country's development and human life. Precision forestry uses high technology sensing and analytical tools or software to support site specific assessment. Adequate quality information derived from precise data helps in maximizing economic return for good decision making. Any information gained from surveying processes should

provide sufficient data to support biodiversity assessment and other environmental resources including maintaining the quality of the environment. Precision forestry is also refers to site specific management. Site specific forest management may be refers to precise information of the tree stand such as measured tree volume from ground measurement and correlates with remote sensing data and GIS technique and/or and may be soil information of the specific forest land. The combination of field checking, aerial photo interpretation/remotely sensed data and data interpretation will refine details for the planning process.

In precision forestry the quality of information is depend to the quality of data acquisition. Nohr (2001) stated that information quality can be defined as the sum of all requirements expected from information (data) in order to fulfil specific information needs. Olson (2003) defined data quality as two consentient aspects: first, the dependence of perceived quality on the user's needs; second, the so-called "fitness for use", which is the ability to satisfy the requirements of intended use in a specific situation. Among the most important criteria about the quality of information are:

Accuracy: Accurate information describes properties or the state of relevant objects according to the reality. If the entity can be described with measurable variables the degree of accuracy can be described easily.

Reliability: The user of information should be convinced that any information available is correct in the widest sense. Even if a high accuracy is given for any variable it might be less reliable because of the measurement procedure used.

Relevancy and process orientation: Information of high quality should meet objectively given information needs. Although this criterion seems to be quite understandable, it is one of the more difficult ones. In particular in forest management decision making is often based on individual approaches of information use.

Timeliness: Information that is not available in time is useless and therefore of very low quality.

Completeness: Incomplete information which misses several and crucial parts may be misleading. Normally decisions are based on complex sets of information which add up to a comprehensive picture of the situation to be considered.

Presentation: This criterion deals with the fact that information needs to be presented in a suitable manner. As information needs to be interpreted in order to prepare decisions appropriate presentation is an important quality issue. Although the criteria mentioned above are not listed according to a hierarchy, they will be of different importance in different enterprises.

The types of tools applied in precision forestry are varies. For measurement and monitoring tools; LiDAR, remotely sensed data can be used to develop highly forest canopy characteristic, digital elevation model (DEM) and digital surface model (DSM) which are useful to determine stream lines and topography under canopy. In electronic mapping the

global positioning system (GPS) and inertial navigation system (INS) were used for navigation under forest canopy. Then GIS is common software which uses for data management and recently web based data management also play a role in huge data storage and management. Next the decision support system (DSS) takes place by optimization of spatial data and simulates the scenario. The capability of ICT based operation research techniques in supporting DSS were proven by the simulation and network analysis (to name a few). The multi criteria decision analysis (MCDA) is widely used and recognized as a solution for the DSS in decision making process.

III. LiDAR AT A GLANCE

LiDAR stands for Light Detection and Ranging and is very similar to the radar. LiDAR is a better choice than radar because it has a greater ability to reflect images, making more objects visible. The principle of LiDAR system is a laser ranging. According to Young (1986) a high directional optical light could be created with laser process, thus yielding the high collimation and high optical power required for ranging. The advantages of laser was it demonstrated the high energy pulse that can be realized in short intervals and short wavelength light which it can be highly collimated using small aperture. Laser light has a much shorter wavelength that make it possible to accurately measure much smaller object such as cloud particle and creates wave form. The ability of laser sensing the points over the path or swath define by the instruments scan angle and altitude of the platform. Equipped with receiver and scanning system the distribution of points cloud using previous profiling system were scanned to the along track path of the aircraft or vehicles. The use of GPS with LiDAR is only deployed in the 1980s to allow precise positioning of aircraft. LiDAR is categorised as an "active" remote sensing because the sensor both emits and records the radiation signal in the form of frequent, short-duration laser which is not record radiation reflected by the surface from a source external (such as sun) to the sensor. In general LiDAR technology has application in geomatics, archaeology, geography, geology, geomorphology, seismology, forestry, remote sensing and atmospheric physics (Cracknell and Hayes, 2006).

As comparison LiDAR uses waves ten to one hundred thousand times shorter than radar waves. This is why LiDAR are able to collect much more information. The elapsed time from when a laser is emitted from a sensor and intercepts an object can be measured using either pulsed ranging or continuous wave. Pulsed ranging is where the travel time of a laser pulse from a sensor to a target object is recorded, meanwhile continuous wave is where the phase change in a transmitted sinusoidal signal produced by a continuously emitting laser is converted into travel time (Wehr and Lohr, 1999). The development of LiDAR technology is parallel through applications of GPS and inertia navigation system (INS) also referred to as inertial measurement units (IMU). LiDAR technology for terrestrial applications differ in (1) whether they record the range to the first return, last return, multiple returns, or fully digitize the return signal, (2)

footprint size (from a few centimeters to tens of meters), and (3) sampling rate/scanning pattern.

LiDAR has some advantages. The advantages of LiDAR are able to carry out direct sampling for measuring vertical and horizontal of forest structure, flexibility in operation (day and night capture), fast delivery times. High resolution and accuracy (tree height measurement and superior DEM generation), ease of GIS integration, cost effective for large scale project and provide wall-to-wall coverage. Other advantages are ability to define terrain under vegetation, typical data vertical accuracy of 0.15m rms, typical point spacing of 1m, and acquiring over 500 million data points per hour. Most commercial airborne LiDAR systems are low-flying, small-footprint (5–30 cm diameter), high pulse rate systems (1000–10,000 Hz). In addition, most commercial LiDAR systems record the range to the highest, and/or lowest, reflecting surface within the footprint, and are not fully imaging, using instead many laser returns in close proximity to each other to recreate a surface.

IV. OVERVIEW OF LiDAR APPLICATIONS IN MALAYSIA

Malaysia is aware the emerging of LiDAR in market to be applied in various sector that can benefit users in managing natural resources. In MAPMalaysia conference on April 2011 in Sabah the LiDAR session Emerging Trends, LiDAR and 3D was attracted by many attendances from delegates. Successful implementation of precision forestry depends on numerous factors, including the extent to which conditions within a field are known and manage, the adequacy of input recommendation and the degree of application. The enabling technologies of precision forestry can be integration of five major components: remote sensing, GIS, global positioning system (GPS), computers and application.

Malaysia is developing country where any development of the forestland for other purposes is subject to environmental impact assessment report and guidelines by the government. The use of LiDAR for surveying and monitoring residential development project was tested in Bukit Tinggi area in Pahang, Malaysia. The project was carried out by the RS & GIS Consultancy Sdn. Bhd. The aim of the project beside to develop the area for low density residential, it also maintain the greenness of the area by minimizing the environmental impact. The big trees were conserved and very minimum slope cutting was done. The rationale is to maintain the ecosystem of the area. Figure 1 showing LiDAR “point clouds” of residential home at nearby Bukit Tinggi, Pahang, Malaysia surrounded by natural forest. Apart from the LiDAR terrain survey, this company also offers advanced geospatial support services to develop the necessary information layers to meet the landscape design and planning initiatives in the area of interest. Besides generating high-resolution Digital Terrain Models (DTM), they also offer to develop detailed contour and slope classification layers, support vital analysis of drainage, road, and culvert design, and analyze layouts and view-sheds of various development options to be explored. These are important to meet the goal in biodiversity conservation, enhancement and sustainable development.

In Kuala Lumpur city an 88-storeys PETRONAS Twin Towers (PTT) was completed in 1998. The PTT is an integral part of the Kuala Lumpur City Centre (KLCC) project. The PTT became the tallest buildings in the world on the date of completion (Sebestyen, 1998). Although PTT is surpassed by the Taipei 101 in 2004, but it still remain as the tallest “Twin building” in the world (Palmer, 2008). It rises to 451.9 m in height and surrounded by public park namely KLCC park which spanned about 10 ha. below the building. Figure 2 shows the KLCC with twin tower by using LiDAR data. The color coded data is capable to portray the scenes with amenities available such as jogging and walking paths, a fountain with incorporated light show, wading pools, and a children's playground.

Other experience was a collaboration study between Universiti Putra Malaysia (Faculty of Engineering and Faculty of Forestry with Limitless Company in Dubai). The aim of the study was to monitor and locating tree in city of Dubai along the overhead transmission cables and cut them whenever trees are overcrossing the cables. A Limitless Dynamic Laser Scanning System owned by Limitless LCC, a Dubai World Company was used for data acquisition (Figure 3). The system structure is basically equipped with laser scanner mounted on top of land cruiser and connected to GPS for positional floating navigation and IMU (Inertial Measurement Unit) to track the system orientation movements. The integration of GPS and IMU unit are the bases in developing dynamic laser scanning in providing an accurate location and orientation of the scanned features (Mahmoud *et al.*, 2010).



Figure 1. LiDAR “point clouds” of residential home at Bukit Tinggi, Pahang, Malaysia surrounded by natural forest.



Figure 2. LiDAR color coded point cloud of the KLCC showing world's tallest twin building in Kuala Lumpur (451.9 m).



Figure 3. Dubai World, Limitless Dynamic Laser Scanning System equipped with IMU and GPS.

Two dynamic laser scanning missions were conducted in two locations (Figure 4). The first mission conducted in Dubai, Limitless LLC, Zone one, where the positional extent of the study area within Latitude $58^{\circ} 24' 44''\text{N}$ to $58^{\circ} 24' 41''\text{N}$ and Longitude $55^{\circ} 05' 34''\text{E}$ to $55^{\circ} 05' 36''\text{E}$. The vehicle speed was set between 10 to 15 km/h. This range is adequate to collect the the intensity of the point cloud that could reflects the shape and location of the trees, although slowing down the vehicle speed would slightly enhance the data. The data were procesed to positioning the accurate location, filtration process to remove unwanted point clouds. The ground observation was conducte and subjected to post processing . The surveyed laser scanning data, post processing and LAS file generation were conducted using the Applanix equipments and the related POSPac software, where the color coded 3D surface generation was conducted using Quick Terrain software.

The ouput of the study area is shown in Figure 5. Laser scanning system is capable in monitoring the overall city features including the city trees. The color reflecting the features elevations where cyan is reflecting the ground surface then green, yellow, orange and red. The black objects are either invisible features or it is non-reflective surface such water or asphalt pavement. This scene also show the importance of the accessibility of the concerned city trees in order to avoid any dark areas and to reflect the physical conditions. The high brightness along the road is generated due to the high reflectivity of the features which also reflects the shape resolution of the features. Results showed that the laser scanning was capable to recognize the trees height and shape/extension. The schematic map in Figure 6 imposed on the color coded image showing the selected tree height, where this case the tree height was 6.5 m and it extension was 18 m. The results are showing the feasibility of conducting the dynamic laser scanning as part of the regular overhead transmission lines maintenance. Meanwhile Figure 7 shows the tree shape and extent from second LiDAR mission of the study area.

The dynamic laser scanning is very effective in reflecting city trees location and acceptable outcome in terms of trees shapes. The positional accuracy is very encouraging in both vertical and horizontal directions. The horizontal coordinates

are re-projected to the local datum in UAE-Dubai (DLTM), where the vertical coordinates are ellipsoidal heights. The dynamic laser scanning is well performed in maintaining the overhead cables from any damages caused by the trees due to the ability of calculating the trees height in sufficient accuracy (up to 10 cm). The outcomes are comparable with aerial LiDAR outcomes where the coverage is less but the accuracy is more and the operational cost is less.



Figure 4. Location of study area (Limitless LLC, Zone One)

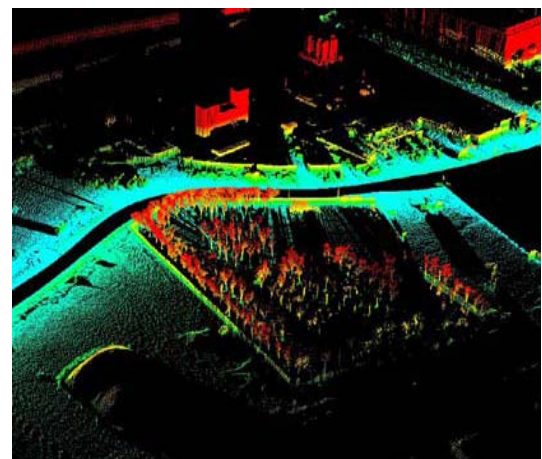


Figure 5. Dynamic LiDAR scanning outcomes of the study area

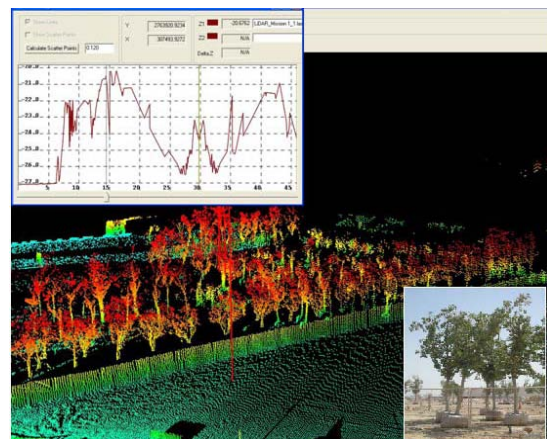


Figure 6. Calculating the trees height and shape/extension from LiDAR data

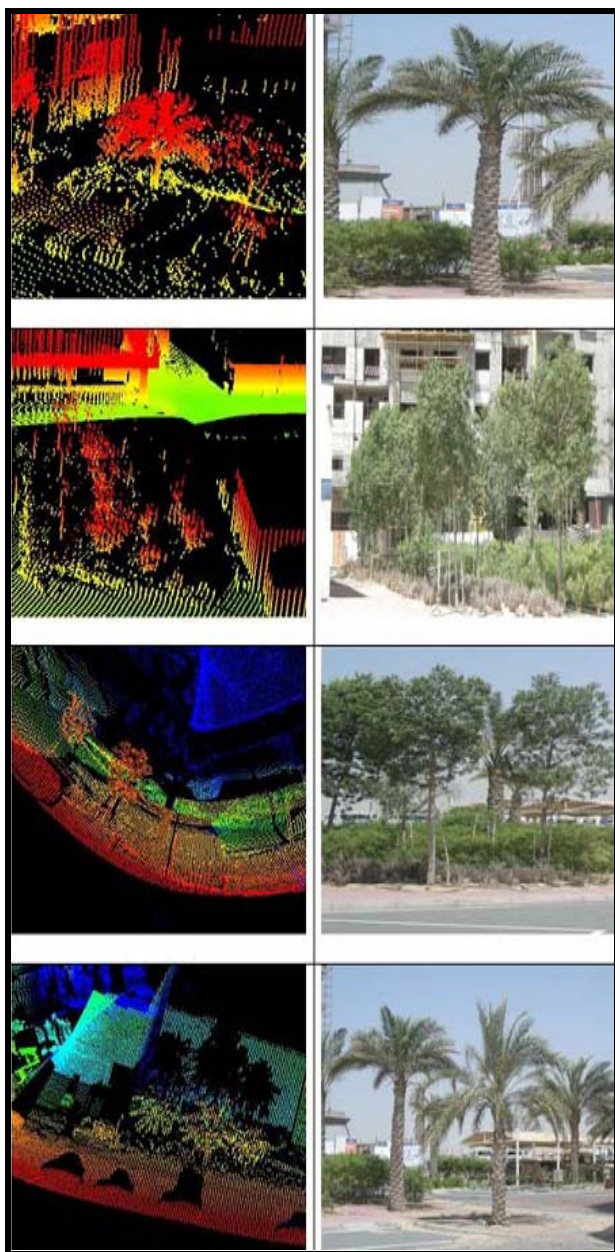


Figure 7. A color coded extracted trees locations and shapes from the second LiDAR Mission

V. CONCLUSION

There are huge potential of using LiDAR technology for precision forestry in many developing countries including Malaysia. The adoption of LiDAR technology in precision forestry also depends on product reliability, the support provides by manufacturers and the ability to show the benefits. The potential of LiDAR in forestry application in Malaysia is wide and require knowledge and techniques to process LiDAR data. However it is clear that LiDAR applications in forestry will continue to increase. We believe the theoretical understanding of the relationships that exist between forest structure and LIDAR response is still incomplete. In general, the most important where the LiDAR can play a significant role is in some of the research area such as canopy and tree

height estimation, LiDAR for forest structure and biomass and volume. Other aspect of a LiDAR need to be emphasized is how much the intensity component of the laser return signal is adequate as a source information to forestry application. On the other hand, data fusion between LiDAR and other remote sensing images is becoming a topic in itself. LiDAR technology will become integrate with digital cameras and also by effective fusion techniques with photogrammetry and multispectral information. Finally, by integrating LiDAR systems with imaging sensors, more advance techniques will emerge, thereby satisfying the wide range of data requirements for forestry application at local and regional scales.

REFERENCES

- [1] Cracknell, A.P., Hayes, L., 2006. Introduction to remote sensing (2 ed.). London: Taylor and Francis, UK.
- [2] Hunter, G., Cox, C., Kremer, J., 2006. Development of a commercial laser scanning mobile mapping system – StreetMapper. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 36; Available online at: <http://www.isprs.org/proceedings/XXXVI/1-W44/www.pegasus4europe.com/>
- [3] Jason, B. D., Ralph, O., Dubayaha, D.B., Clark, B.C., Robert, G. K., Bryan, B., Michelle, A. H., Robin L. C., John, F. W., Stephen, D. P., 2002. Estimation of tropical forest structural characteristics using large-footprint lidar. Remote Sensing of Environment, 79, 305– 319.
- [4] Lefsky, M.A., Cohen, W.B., Parker, G.G., Harding, D.J., 2002. Lidar remote sensing for ecosystem studies. Bioscience, 52(1), 19-30.
- [5] Mahmoud, F.A., Ahmad, R., Mohd Hasmadi, I., Alias, M.S., 2010. Utilization of the dynamic laser scanning technology for shielding the overhead electrical cables by developing a smart monitoring for city tree progress. Int. J. of Information Processing and Management, 2(1), 148-159.
- [6] Mohd Hasmadi, I., Kamaruzaman, J., Pakhriazad, H.Z., Frisco, N., 2007. Geoinformatics for better forest management. Poster paper presented at the National Conference on the Management & Conservation of Forest Biodiversity in Malaysia: Forest Biodiversity for Better Life, 20-21 March, 2007, Marriot Hotel, Putrajaya, Malaysia. 12p.
- [7] Murphy, G.E., 2008. Determining stand value and log product yields using terrestrial lidar and optimal bucking: a case study. Journal of Forestry, 106(6), 317-324.
- [8] Nohr, H., 2001. Management der Informationsqualität, Nr. 3/2001, Fachhochschule Stuttgart, Stuttgart.
- [9] Olson, J.E., 2003. Data quality - The Accuracy Dimension, Morgan Kaufmann Publishers, San Francisco.
- [10] Palmer, A.L., 2008. Historical dictionary of architecture: The Scarecrow Press, Inc.
- [11] Popescu, S. C., Wynne, R. H., Scrivani, J. A., 2004. Fusion of small footprint lidar and multispectral data to estimate plot-level volume and biomass in deciduous and pine forests in Virginia, U.S.A. Forest Science, 50(4), 551-565.
- [12] Reutebuch, S.E., Andersen, H.E., McGaughey, R.J., 2005. Light detection and ranging (LIDAR): An emerging tool for multiple resource inventory. Jour. For. Sept., 286-292.
- [13] Richardson, J., Moskal, L. M., Kim, S., 2009. Modeling approaches to estimate effective leaf area index from aerial discrete-return LIDAR., Agricultural and Forest Meteorology, 149, 1152-1160.
- [14] Sebestyen, G., 1998. Construction: Craft to industry. London: Taylor & Francis, UK.
- [15] Wehr, A., Lohr, U., 1999. Airborne laser scanning – an introduction and overview. ISPRS Journal of Photogrammetry and Remote Sensing, 54, 68-82.
- [16] Young, M., 1986. Optics and lasers: Including fibers and optical waveguide. Berlin, Springer Verlag.